This ETL presents background information concerning UV disinfection of secondary treated wastewater, basic design considerations and criteria, specification considerations, equipment descriptions and testing requirements. A design procedure is explained and an example problem included.

2. BACKGROUND

2.1 Disinfection of Wastewater

Wastewater disinfection processes involve specialized treatment for the destruction or removal of organisms capable of giving rise to infection(10). Disinfection processes have been employed to destroy or inactivate disease causing microorganisms, primarily bacteria of intestinal origin. The term disinfection now has a meaning of inactivation of all microorganisms which cause disease, i.e. pathogenic bacteria, protozoa, and waterborne viruses(10,11). Disinfection can be achieved by a variety of methods including chlorine, calcium and sodium hypochlorite, chlorine dioxide, chloramine, ozone, and ultraviolet light radiation. Other means, utilized to a lesser degree, are iodine, bromine chloride, potassium permanganate, hydrogen peroxide, metal ions, heat, ultrasonics, and electrostatic processes. This ETL deals exclusively with the ultraviolet disinfection process.

2.2 Disinfection with Ultraviolet Radiation

The disinfecting potential of ultraviolet light has been known for many years (10). In 1877 it was discovered that the ultraviolet radiation of the sunlight spectrum could destroy bacteria and that the germicidal action was associated mainly with the short wavelength component of the solar radiation (10,11). In 1893 it was shown that the UV radiation of the sunlight was responsible for the germicidal action. The germicidal effect of ultraviolet light is thought to be associated with its absorption by various organic molecular components essential to the functioning of cells(10,12). Ultraviolet light has been proven effective against many microorganisms but the effectiveness varies with microbe type. A higher dose is required to inactivate bacterial and fungal spores than to destroy vegetative cells. Ultraviolet light is also effective against viruses with a two-log reduction in viral concentration shown in wastewater treatment plants using ultraviolet disinfection(10,13).

2.3 Application to Wastewater Disinfection

The application of UV light to the disinfection of wastewater has become a well established technique with installations exceeding one mgd dating back to 1967. Prior to this, and despite the widespread recognition of UV as a disinfectant, it's use was confined to treatment of potable water. However, increased knowledge of ultraviolet transmission, improved lamp and equipment design, attention to operation and maintenance, and the absence of a residual have been significant factors in the application of UV disinfection technology to wastewater. Because wastewater is considered homogeneous relative to concentrations of constituents and bacteria, an effective UV system can transmit the germicidal radiation through the entire waste stream. This has been accomplished by reducing the distance of wastewater from the UV source, by providing enough turbulence to mix the wastewater stream, and by lengthening the UV exposure time[25].

Other improvements have been made to keep the lamp surfaces clean in order to maintain maximum transmittance and the UV equipment provided is now able to compensate for water quality considerations such as turbidity, color, and suspended solids which would otherwise result in decreased light penetration and less disinfecting potential.

The two major requirements for disinfection of potable water, namely, the need to maintain residual protection during transport to the consumer and total kill of raw water sources of high turbidity, are not valid for secondary wastewater since there is no need to maintain a residual and the process only has to leave about 200 counts/100 ml fecal coliform. Both of these criteria are desirable characteristics when discharging treated wastewater to natural receiving waters.

2.4 Advantages and Disadvantages of UV Disinfection

Some advantages of UV for disinfection over alternative methods include: (a) excellent disinfection performance with bacteria and viruses; (b) short contact times required to inactivate viruses and bacteria (exposure time on the order of seconds); (c) no undesirable by-products such as assimilable organic carbon (AOC) or carcinogenic halogenated compounds created; (d) no chemical additions required, no dangerous chemicals or gases for operators to store and handle, and no chemical or physical changes to the disinfected effluent; (e) no potential harm to fish, wildlife, or humans downstream; (f) no detrimental effects produced by over-dosing as with chemical and gaseous disinfectants; and (g) lower cost than most alternative methods of disinfection.

Some disadvantages of UV disinfection include: (a) possibility of re-activation of irradiated microorganisms if exposed to energy wavelengths in the visible light range; (b) limited information on factors influencing effectiveness in practice; (c) uncertainties regarding accuracy and reliability in measuring UV dose because current systems rely on sensors and theoretical measurements; (d) frequent and expensive apparatus maintenance is necessary to ensure efficient light energy intensity application and uniform light density throughout the effective radiation area; and (e) treatment efficiency is not readily determinable because of lack of a rapid field test.

2.5 Disinfection Standards

Historically, individual states have established and controlled wastewater disinfection practices in the U.S. with emphasis on protection of public health, particularly where contact with wastewater is likely to occur[25]. An attempt was made by EPA in the Clean Water Act, PL 92-500, in October 1972 and in the Secondary Treatment Information Regulation of August 1973 by the EPA for national effluent standards including a fecal coliform standard applicable to all wastewater disinfection situations. Because of variation in impact on costs and benefits for site specific cases, the EPA withdrew the regulations and returned control of wastewater disinfection practices to the states. Today disinfection requirements are implemented through National Pollutant Discharge Elimination System (NPDES) permits issued to individual treatment plants which set effluent limitations in terms of indicators of pathogenic contamination (i.e. coliform bacteria) based on the desired use of the receiving water.

The generally accepted criteria for disinfection, based on water use, are as follows[26,27]:

a. Where shellfish are grown for human consumption, the median coliform densities should be 14 fecal coliform or 70 total coliform per 100 ml,

b. Where whole body contact of a receiving water is desired, the geometric mean over a 30-day period should not exceed 200 fecal coliform bacteria per 100 ml, with a maximum 7-day average of 400 per 100 ml,

c. Where secondary contact recreation is desired, such as boating, in-stream levels may be from 1,000 to 5,000 fecal coliform per 100 ml.

The predominant effluent criteria used in specifying performance requirements for UV systems at military facilities is that for whole body contact.

As a result of the concern associated with the dangers of chlorinated effluent and in particular the formation of trihalomethane (THM), many states have already enacted legislation limiting the amount of chlorine allowed in an effluent discharge. Limitations of 0.01 ppm require de chlorination ar an alternative method of disinfection such as UV.

2.6 Special Requirements

Several considerations should be included in the design and operation of a UV disinfection system. First, it must be simply designed and constructed, and must be provided with reliable equipment that is not labor intensive or complex in terms of maintainability, serviceability, and availability of parts. Second, the trend is toward limited operator manpower availability at Army treatment plants and this must be considered in the design. Third, operator safety must be incorporated in the design process.

3. FUNDAMENTALS OF ULTRAVIOLET DISINFECTION

3.1 Nature of Ultraviolet Light[34]

Ultraviolet light is invisible radiation within a range of the electromagnetic spectrum having a wavelength between 100 and 400 nanometers (nm). One nanometer unit wavelength equals 10 Angstroms, Å.